(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 4 400 354 A1

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
17.07.2024 Bulletin 2024/29

(21) Application number: **21955278.3**

(22) Date of filing: **06.09.2021**

(51) International Patent Classification (IPC):
B60L 15/20 *(2006.01)*

(52) Cooperative Patent Classification (CPC):
B60L 15/20; Y02T 10/72

(86) International application number:
PCT/JP2021/032723

(87) International publication number:
WO 2023/032221 (09.03.2023 Gazette 2023/10)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(71) Applicant: **NISSAN MOTOR CO., LTD.**
Kanagawa 221-0023 (JP)

(72) Inventor: **OGINO, Takashi**
Atsugi-shi, Kanagawa 243-0123 (JP)

(74) Representative: **Hoefer & Partner Patentanwälte mbB**
Pilgersheimer Straße 20
81543 München (DE)

(54) **DRIVING FORCE CONTROL METHOD AND DRIVING FORCE CONTROL DEVICE**

(57) A driving force control method for controlling front wheel driving force and rear wheel driving force by a front wheel motor connected to a front wheel of a vehicle and a rear wheel motor connected to a rear wheel, respectively, the driving force control method including: executing a cooperative process of lifting up or lifting down a vehicle body by cooperation of adjustment of at least one of the front wheel driving force and the rear wheel driving force and application of friction braking force to at least one of the front wheel and the rear wheel.

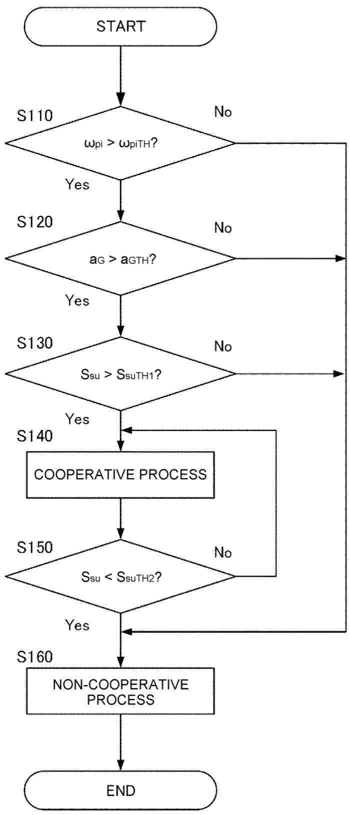


FIG. 4

EP 4 400 354 A1

Description

TECHNICAL FIELD

[0001] The present invention relates to a driving force control method and a driving force control device.

BACKGROUND ART

[0002] In JP 2007-118898 A, there has been proposed a braking and driving force control device that detects a pitch rate (pitch angular velocity) when an in-wheel motor type vehicle passes through a step of a road surface to apply different braking and driving force to front and rear wheels so as to reduce the detected pitch rate (displacement in a pitch direction) when an effect of suspension is not sufficiently achieved in the in-wheel motor type vehicle.

SUMMARY OF INVENTION

[0003] Depending on a traveling scene of the vehicle, there may be a case in which vehicle body displacement (heave vibration) in a vertical direction is mainly large, and control of reducing this is desired. However, in the above-described control of reducing the displacement in the pitch direction by applying the different braking and driving force to the front and rear wheels, there is a problem that an effect of reducing the displacement in the vertical direction is limited.

[0004] An object of the present invention is to provide a driving force control method and a driving force control device that can further improve an effect of reducing vertical displacement of a vehicle.

[0005] According to an aspect of the invention, provided is that a driving force control method for controlling front wheel driving force and rear wheel driving force by a front wheel motor connected to a front wheel of a vehicle and a rear wheel motor connected to a rear wheel, respectively. The driving force control method includes executing a cooperative process of lifting up or lifting down a vehicle body by cooperation of adjustment of at least one of the front wheel driving force and the rear wheel driving force and application of friction braking force to at least one of the front wheel and the rear wheel.

BRIEF DESCRIPTION OF DRAWINGS

[0006]

[FIG. 1] FIG. 1 is a diagram illustrating a configuration of a vehicle in which a driving force control method according to an embodiment of the present invention is executed.

[FIG. 2] FIG. 2 is a diagram showing a schematic structure of a chassis system of the vehicle.

[FIG. 3] FIG. 3 is a diagram illustrating an operation and effect of executing a cooperative process.

[FIG. 4] FIG. 4 is a flowchart illustrating a driving force control method according to the present embodiment.

[FIG. 5] FIG. 5 shows timing charts showing examples of time-series changes of control parameters when control according to the present embodiment is executed in an undulation road traveling scene.

[FIG. 6] FIG. 6 shows diagrams illustrating an operation and effect.

DESCRIPTION OF EMBODIMENTS

[0007] Hereinafter, embodiments of the present invention will be described in detail with reference to the drawings.

[0008] FIG. 1 is a diagram illustrating a configuration of a vehicle 100 in which a driving force control method according to the present embodiment is executed. As the vehicle 100 according to the present embodiment, an electric vehicle, a hybrid vehicle, or the like, which includes a drive motor 10 serving as a driving source and can travel by driving force of the drive motor 10, is assumed.

[0009] The drive motor 10 includes a front wheel motor 10f provided at a front position (front wheel side) of the vehicle 100 to drive front wheels 11f, and a rear wheel motor 10r provided at a rear position (rear wheel side) to drive rear wheels 11r.

[0010] The front wheel motor 10f is implemented by a three-phase AC motor. During power running, the front wheel motor 10f is supplied with electric power from an in-vehicle battery (not shown) to generate driving force. The driving force generated by the front wheel motor 10f is transmitted to the front wheels 11f via a front wheel transmission 16f and a front wheel drive shaft 21f. On the other hand, during regeneration, the front wheel motor 10f converts regenerative braking force of the front wheels 11f into AC power and supplies the AC power to the in-vehicle battery.

[0011] On the other hand, the rear wheel motor 10r is implemented by a three-phase AC motor. During power running, the rear wheel motor 10r is supplied with electric power from the in-vehicle battery to generate driving force. The driving force generated by the rear wheel motor 10r is transmitted to the rear wheels 11r via a rear wheel transmission 16r and a rear wheel drive shaft 21r. During regeneration, the rear wheel motor 10r converts regenerative braking force of the rear wheels 11r into AC power and supplies the AC power to the in-vehicle battery.

[0012] An inverter 12 includes a front wheel inverter 12f that adjusts the electric power (positive in the power running and negative in the regeneration) supplied to the front wheel motor 10f, and a rear wheel inverter 12r that adjusts the electric power (positive in the power running and negative in the regeneration) supplied to the rear wheel motor 10r.

[0013] The front wheel inverter 12f adjusts the electric power supplied to the front wheel motor 10f such that positive or negative driving force (hereinafter, also referred to as "front wheel driving force F_f") determined for total driving force (hereinafter, also referred to as "total requested driving force F_{fr}") requested for the vehicle 100 is achieved. On the other hand, the rear wheel inverter 12r adjusts the electric power supplied to the rear wheel motor 10r such that positive or negative driving force (hereinafter, also referred to as "rear wheel driving force F_r") determined for the total requested driving force F_{fr} is achieved.

[0014] In particular, the front wheel driving force Ff and the rear wheel driving force F_r in the present embodiment are determined such that a sum thereof matches the total requested driving force F_{fr}. The total requested driving force F_{fr} is determined based on, for example, an operation amount (accelerator opening) for an accelerator pedal mounted on the vehicle 100, or a command from a prescribed autonomous driving system (autonomous driving control device) such as an advanced driver assistance systems (ADAS) or autonomous driving (AD).

[0015] A brake actuator 14 is constituted by known mechanical brakes operated by hydraulic pressure or the like, and includes front wheel friction brakes 14f that apply friction braking force (hereinafter also referred to as "front wheel braking force Bf") to the front wheel 11f, and rear wheel friction brakes 14r that apply friction braking force (hereinafter also referred to as "rear wheel braking force B_r") to the rear wheel 11r.

[0016] Further, the vehicle 100 further includes a controller 50 serving as a driving force control device that controls the front wheel driving force Ff, the rear wheel driving force F_r, the front wheel braking force B_f, and the rear wheel braking force B_r.

[0017] The controller 50 is implemented by a computer including a central processing unit (CPU), a read-only memory (ROM), a random access memory (RAM), and an input/output interface (I/O interface), and is programmed so as to execute each processing in vehicle control to be described below. In particular, a function of the controller 50 can be achieved by any in-vehicle computer such as a vehicle control module (VCM), a vehicle motion controller (VMC), and a motor controller, and/or a computer provided outside the vehicle 100. The controller 50 may be implemented by one piece of computer hardware, or may be implemented by distributing various processes by a plurality of pieces of computer hardware.

[0018] The controller 50 controls the front wheel driving force Ff, the rear wheel driving force F_r, the front wheel braking force B_f, and the rear wheel braking force B_r by using the total requested driving force F_{fr}, detection values of vertical acceleration sensors 30fL, 30fR on the front wheel side, detection values of vertical acceleration sensors 30rL, 30rR on the rear wheel side, a suspension stroke amount S_{su} detected by a sensor (not shown), and the like as input information. More specifically, the controller 50 issues a command to the front wheel inverter 12f, the rear wheel inverter 12r, the front wheel friction brake 14f, and the rear wheel friction brake 14r so as to achieve desired front wheel driving force Ff, rear wheel driving force F_r, front wheel braking force B_f, and rear wheel braking force B_r.

[0019] In particular, in the present embodiment, the controller 50 executes any one of basic drive control, a cooperative process, and a non-cooperative process as control that defines driving force distribution during forward traveling (particularly, during acceleration) of the vehicle 100.

[0020] The controller 50 executes the basic drive control during normal traveling (in the present embodiment, in particular, a scene other than traveling on an undulation road to be described later). In the basic drive control, the controller 50 sets the front wheel driving force Ff and the rear wheel driving force F_r to prescribed basic front wheel driving force and prescribed basic rear wheel driving force, respectively.

[0021] Here, the basic front wheel driving force and the basic rear wheel driving force are values determined by experiments, simulations, or the like so that vehicle characteristics (in particular, power consumption performance) of the vehicle 100 take desired characteristics according to a traveling scene. Specific values of the basic front wheel driving force and the basic rear wheel driving force may be appropriately changed in accordance with a specification of the vehicle 100 and the traveling scene. For example, when the vehicle 100 travels straight on a flat paved road at a constant speed, a distribution ratio of the basic front wheel driving force and the basic rear wheel driving force to the total requested driving force F_{fr} can be set to 50:50.

[0022] On the other hand, when controller 50 detects a scene in which the vehicle 100 travels on a prescribed undulation road based on various pieces of input information, the controller 50 executes any one of the cooperative process and the non-cooperative process according to a size (amplitude) of an unevenness of the undulation road. In the present embodiment, the undulation road means a traveling road on which an unevenness is present over a certain distance in a traveling direction of the vehicle 100. In the following, in particular, a portion of the undulation road protruding from a flat surface is referred to as a "mountain", and a portion thereof recessed from the flat surface is referred to as a "valley".

[0023] In the cooperative process, the controller 50 executes either a first control mode or a second control mode in response to a request to lift up a vehicle body or a request to lift down the vehicle body.

[0024] In the first control mode, the controller 50 sets the front wheel braking force B_f to a positive value, sets the front wheel driving force Ff to a negative value, and sets the rear wheel driving force Fr to a positive value. That is, the controller 50 causes the front wheel motor 10f to execute regeneration (causes the front wheels 11f to execute regenerative braking), causes the rear wheel motor 10r to execute power running (causes the rear wheels 11r to execute power driving), and then applies the friction braking force to the front wheels 11f. In the second control mode, the controller 50 sets the front wheel driving force Ff to a positive value, sets the rear wheel driving force F_r to a negative value, and sets the rear wheel braking force B_r to a positive value. That is, the controller 50 causes the front wheel motor 10f to execute power running (causes the front wheels 11f to execute power driving), causes the rear wheel motor 10r to execute regeneration (causes the rear wheels 11r to execute regenerative braking), and then applies the friction braking force to the rear wheels 11r.

[0025] On the other hand, in the non-cooperative process, the controller 50 executes either a third control mode or a fourth control mode in response to a request to lift up the vehicle body or a request to lift down the vehicle body.

[0026] In the third control mode, the controller 50 sets the front wheel driving force Ff to a negative value and sets the rear wheel driving force F_r to a positive value without applying the front wheel braking force B_f. Further, in the fourth control mode, the controller 50 sets the front wheel driving force Ff to a positive value and sets the rear wheel driving force F_r to a negative value without applying the rear wheel braking force B_r.

[0027] A relationship between adjustment of the front wheel driving force Ff, the rear wheel driving force F_r, the front wheel braking force Bf, and the rear wheel braking force B_r and reduction of vertical displacement of the vehicle body in the cooperative process and the non-cooperative process will be described more specifically.

[0028] FIG. 2 is a diagram illustrating a schematic structure (particularly, an outline of a suspension geometry) of a chassis system of the vehicle 100. In the figure, "Of" represents a virtual rotation center (instantaneous rotation center) in a pitch direction of a vehicle body front portion, and "O_r" represents a virtual rotation center (instantaneous rotation center) in the pitch direction of a vehicle body rear portion.

[0029] When the vehicle 100 is traveling forward, when the regenerative braking force (force in a direction opposite to the traveling direction) is applied to the front wheels 11f and power driving force (force in the same direction as the traveling direction) is applied to the rear wheels 11r, anti-squat force F_{an} (force for lifting the vehicle body) acts on the vehicle body. On the other hand, when power driving force is applied to the front wheels 11f and regenerative braking force is applied to the rear wheels 11r, squat force F_{sq} (force for causing the vehicle body to sink) acts on the vehicle body.

[0030] Accordingly, theoretically, in the scene in which the vehicle 100 travels on the undulation road or the like, by performing pitch adjustment (that is, the above-described non-cooperative process) by adjusting the driving force distribution of the front wheels 11f and the rear wheels 11r, it is possible to reduce the vertical displacement (heave vibration) of the vehicle body by appropriately lifting up or lifting down the vehicle body.

[0031] On the other hand, a magnitude of the anti-squat force F_{an} or the squat force F_{sq} obtained by the non-cooperative process depends on a magnitude of an anti-squat angle θ (front anti-squat angle θ_f and rear anti-squat angle θ_r) of a suspension 40 (front suspension 40f and rear suspension 40r) of the vehicle 100.

[0032] More specifically, the front wheel driving force Ff generated by the front wheel motor 10f and the rear wheel driving force F_r generated by the rear wheel motor 10r are transmitted to the front wheels 11f and the rear wheels 11r, respectively, with the front wheel drive shaft 21 and the rear wheel drive shaft 21r as working points.

[0033] Therefore, the anti-squat angles θ_f and θ_r, which define a vertical component of pitching force generated by the adjustment of the driving force distribution (that is, the magnitude of the anti-squat force F_{an} or the squat force F_{sq}), are respectively determined as angles formed by a horizontal line and straight lines respectively connecting the virtual rotation centers O_f and O_r determined by structures of the suspensions 40f, 40r and the working points.

[0034] Therefore, in a case in which the anti-squat angles θ_f and θ_r cannot be increased (in a case in which the virtual rotation centers O_f and O_r are located at relatively low positions) due to the structures of the suspensions 40f and 40r, a range of the anti-squat force F_{an} or the squat force F_{sq} obtained by adjusting the driving force distribution is limited.

[0035] In particular, as in the vehicle 100 of the present embodiment shown in FIG. 2, in a case in which a suspension structure in which the front anti-squat angle θ_f is relatively small is adopted in consideration of ride comfort and nose dive feeling during braking, there is a problem that a sufficient effect of reducing the vertical displacement of the vehicle body cannot be achieved even if the non-cooperative process is executed.

[0036] In contrast, the present inventor has found that a high effect of reducing the vertical displacement of the vehicle body can be achieved even in the vehicle 100 equipped with the suspension structure having a relatively small anti-squat angle θ by adjusting net driving force distribution applied to the front wheels 11f and the rear wheels 11r beyond an adjustment range by the non-cooperative process using the front wheel braking force B_r or the rear wheel braking force B_r.

[0037] FIG. 3 is a diagram illustrating an operation and effect of executing the cooperative process. In the following description, in particular, the operation and effect of the cooperative process will be described focusing on the first control mode (application of the front wheel braking force Bf, regenerative braking of the front wheels 11f, and power driving of the rear wheels 11r). On the other hand, the following description also applies to the second control mode (power driving of the front wheels 11f, application of the rear wheel braking force B_r, and regenerative braking of the rear wheels 11r).

[0038] As shown in the figure, when the first control mode is executed while the vehicle 100 is traveling forward, a working point of the front wheel braking force B_r

is an outer peripheral portion of the front wheel 11f. Therefore, an anti-squat angle θ_{Bf} determined as an angle formed by a horizontal line and a straight line that connects the virtual rotation center O_f on the front wheel side and the working point of the front wheel braking force B_r to each other is larger than the anti-squat angle Of in the non-cooperative process. Therefore, when the first control mode of the cooperative process is executed, the effect of reducing the vertical displacement of the vehicle body can be further enhanced compared to when the third control mode of the non-cooperative process is executed.

[0039] On the other hand, the cooperative process is control of operating the mechanical brake actuator 14. Therefore, in terms of control responsiveness, the non-cooperative process, which is electrical control without operation of a mechanical actuator, is superior.

[0040] Hereinafter, an example will be described in which, in a scene in which the vehicle 100 travels on an undulation road, a situation in which the reduction of the vertical displacement of the vehicle body is prioritized and a situation in which the control responsiveness is prioritized are distinguished according to the size of an unevenness of a traveling road surface, and one of the cooperative process and the non-cooperative process is appropriately executed.

[0041] FIG. 4 is a flowchart illustrating the driving force control method according to the present embodiment. Each process shown in FIG. 4 is executed based on a timing at which the controller 50 determines that the vehicle 100 is traveling on the undulation road based on information of a traveling road provided from a prescribed internal sensor or an external server mounted on the vehicle 100. In particular, the controller 50 repeatedly executes each process shown in FIG. 4 at prescribed calculation intervals in the scene.

[0042] In steps S110 and S120, the controller 50 determines whether a pitch rate ω_{pi} and vertical acceleration a_G exceed a pitch rate threshold value ω_{piTH} and a vertical acceleration threshold value a_{GTH}, respectively.

[0043] Here, the pitch rate ω_{pi} is a parameter defined as a time derivative (that is, a pitch angular velocity) of a pitch angle θ_{pi}. Further, the pitch angle θ_{pi} is determined as a displacement angle in the pitch direction with respect to a horizontal direction around a center of gravity G of the vehicle 100 (see FIG. 2). A sign of the pitch angle θ_{pi} is set such that a direction in which the front wheel 11f of the vehicle 100 is lifted up (nose up direction) is positive and a direction in which the rear wheel 11r is lifted up (nose down direction) is negative. Further, the vertical acceleration a_G is acceleration in the vertical displacement of the vehicle 100 (center of gravity G of the vehicle 100). The pitch rate ω_{pi}, the pitch angle θ_{pi}, and the vertical acceleration a_G can be calculated by a known method based on the detection values of the vertical acceleration sensors 30fL, 30fR on the front wheel side, the detection values of the vertical acceleration sensors 30rL, 30rR on the rear wheel side, and other necessary parameters.

[0044] Both the pitch rate ω_{pi} and the vertical acceleration a_G are parameters representing magnitude of the actual vertical displacement of the vehicle 100 during traveling on the undulation road. That is, both the pitch rate ω_{pi} and the vertical acceleration a_G are parameters (unevenness degree parameters) indicating the size of the unevenness of the undulation road.

[0045] Further, the pitch rate threshold value ω_{piTH} and the vertical acceleration threshold value a_{GTH} are determined as values to appropriately determine which of the effect of reducing the vertical displacement of the vehicle 100 and the high control responsiveness is prioritized. More specifically, the pitch rate threshold value ω_{piTH} and the vertical acceleration threshold value a_{GTH} are determined so that the cooperative process is executed when the unevenness of the undulation road is relatively large (when the high control responsiveness is not required, but the high effect of reducing the vertical displacement is required). Conversely, the pitch rate threshold value ω_{piTH} and the vertical acceleration threshold value a_{GTH} are determined such that the non-cooperative process is executed when the unevenness of the undulation road is relatively small (when the high control responsiveness is required, but the required effect of reducing the vertical displacement is small).

[0046] Further, the controller 50 executes a process of step S 130 when both determination results of step S110 and step S 120 are positive, and otherwise executes the non-cooperative process (step S160).

[0047] In step S130, the controller 50 determines whether the suspension stroke amount S_{su} exceeds a first stroke amount threshold value S_{suTH1}.

[0048] Similarly to the pitch rate ω_{pi} and the vertical acceleration a_G, the suspension stroke amount S_{su} is also an unevenness degree parameter representing the magnitude of the actual vertical displacement of the vehicle 100 during traveling on the undulation road. Further, the first stroke amount threshold value S_{suTH1} is also set to a suitable value from the viewpoint of determining whether the unevenness of the undulation road is large to an extent that the reduction of the vertical displacement of the vehicle 100 by the cooperative process using the front wheel braking force B_r or the rear wheel braking force B_r is desired.

[0049] Further, when a determination result of step S130 is positive, the controller 50 executes the cooperative process (step S140), and otherwise, executes the non-cooperative process (step S160).

[0050] As a specific example of the cooperative process, the controller 50 executes the first control mode (lifts up the vehicle body) so as to cancel force in a lift down direction in a scene in which the vehicle 100 is traveling on a valley portion of the undulation road and the force in the lift down direction is generated on the vehicle body. On the other hand, the controller 50 executes the second control mode (lifts down the vehicle body) so as to cancel force in a lift up direction in a scene in which the vehicle

100 is traveling on the mountain of the undulation road and the force in the lift up direction is generated on the vehicle body.

[0051] Further, as an example of the non-cooperative process, the controller 50 executes the third control mode (lifts up the vehicle body) so as to cancel force in the lift down direction in a scene in which the vehicle 100 travels on the valley portion of the undulation road and the force in the lift down direction is generated on the vehicle body. On the other hand, the controller 50 executes the fourth control mode (lifts down the vehicle body) so as to cancel force in the lift up direction in a scene in which the vehicle 100 is traveling on the mountain of the undulation road and the force in the lift up direction is generated on the vehicle body.

[0052] An aspect of selection of the first control mode or the second control mode in the cooperative process and an aspect of selection of the third control mode or the fourth control mode in the non-cooperative process described above are examples, and the present invention is not limited thereto. Specific values of the front wheel driving force Ff, the rear wheel driving force F_r, the front wheel braking force B_f, and the rear wheel braking force B_r set in the cooperative process or the non-cooperative process are not limited to specific values, and can be appropriately adjusted according to a situation.

[0053] Further, the controller 50 determines whether the suspension stroke amount S_{su} falls below a second stroke amount threshold value S_{suTH2} during the execution of the cooperative process (step S150).

[0054] The second stroke amount threshold value S_{suTH2} is set to an appropriate value from the viewpoint of determining whether the unevenness of the undulation road is small enough to determine that it is necessary to switch from the cooperative process to the non-cooperative process in consideration of the control responsiveness.

[0055] Further, when the controller 50 determines that the suspension stroke amount S_{su} falls below the second stroke amount threshold value S_{suTH2}, the controller 50 switches the control from the cooperative process to the non-cooperative process (step S160) and ends this routine.

[0056] In consideration of low control responsiveness in the above-described cooperative process, a configuration may be adopted in which the switching from the cooperative process to the non-cooperative process is executed when the suspension stroke amount S_{su} falls below the second stroke amount threshold value S_{suTH2} a plurality of times. In particular, it takes a certain amount of time until the effect of reducing the vertical displacement of the vehicle body is actually obtained after the cooperative process is started according to the determination result of step S130. In consideration of this, it is possible to prevent a situation where a state in which the suspension stroke amount S_{su} is temporarily decreased is detected and the control is switched to the non-cooperative process even though the front wheel braking force B_r or the rear wheel braking force B_r has not yet followed the command immediately after a start of the cooperative process or the like. Further, in determination of step S 150 (determination of whether to switch from the cooperative process to the non-cooperative process), a configuration may be adopted in which the pitch rate ω_{pi} and/or the vertical acceleration a_G are appropriately compared with the threshold values.

[0057] FIG. 5 shows timing charts showing examples of time-series changes of control parameters when the control according to the present embodiment is executed in an undulation road traveling scene. In the timing charts of FIG. 5, the pitch angle θ_{pi} and the pitch rate ω_{pi} are positive in the nose up direction of the vehicle 100, the vertical acceleration a_G is positive in an upward direction with respect to the vehicle 100, and the suspension stroke amount S_{su} is positive in a compression direction of the suspension 40.

[0058] As shown in the drawing, in a section (time $t < t1$) in which any one of the pitch rate ω_{pi}, the vertical acceleration a_G, and the suspension stroke amount S_{su} is equal to or less than a respective one of the threshold values, that is, in a scene in which the unevenness of the undulation road is estimated to be relatively small, the non-cooperative process is executed with priority given to the control responsiveness.

[0059] Further, when all of the pitch rate ω_{pi}, the vertical acceleration a_G, and the suspension stroke amount S_{su} (particularly, in FIG. 5, the suspension stroke amount S_{su} on the rear wheel side) exceed the respective threshold values (time t = t1), that is, when the vehicle 100 is estimated to enter a section in which the unevenness of the undulation road is relatively large, the control is switched from the non-cooperative process to the cooperative process from the viewpoint of improving the effect of reducing the vertical displacement of the vehicle body.

[0060] Thereafter, when the suspension stroke amount S_{su} (in FIG. 5, the suspension stroke amount S_{su} on both the front wheel side and the rear wheel side) falls below the second stroke amount threshold value S_{suTH2}, that is, when the vehicle 100 is estimated to enter a section in which the unevenness of the undulation road is relatively small, the control is switched from the cooperative process to the non-cooperative process again.

[0061] FIG. 6 shows diagrams illustrating an operation and effect of executing the control described in the timing charts of FIG. 5. As shown in the figure, the pitch rate ω_{pi}, the vertical acceleration a_G, and the suspension stroke amount S_{su} (see broken lines), which are parameters indicating the magnitude of the vertical displacement in the control according to the present embodiment, are reduced compared to those (see solid lines) in a comparative example in which the basic drive control is maintained even during traveling on the undulation road.

[0062] Hereinafter, a configuration of the above-described present embodiment and an operation and effect thereof will be collectively described.

[0063] The present embodiment provides the driving force control method for controlling the front wheel driving force Ff and the rear wheel driving force F_r by the front wheel motor 10f connected to the front wheels 11f of the vehicle 100 and the rear wheel motor 10r connected to the rear wheels 11r, respectively.

[0064] In this driving force control method, the cooperative process (step S140) is executed in which the adjustment of at least one of the front wheel driving force Ff and the rear wheel driving force F_r and the application of the friction braking force (front wheel braking force B_f or rear wheel braking force B_r) to at least one of the front wheel 11f and the rear wheel 11r cooperate to lift up or lift down the vehicle body.

[0065] Accordingly, it is possible to further improve the effect of reducing the vertical displacement (heave vibration) of the vehicle 100 compared to the case in which the vehicle body is lifted up or lifted down by control of adjusting only the front wheel driving force Ff and the rear wheel driving force F_r.

[0066] In particular, the cooperative process (step S140) includes the first control mode in which the vehicle body is lifted up and the second control mode in which the vehicle body is lifted down. Further, in the first control mode, the friction braking force (front wheel braking force Bf) is applied to the front wheels 11f to power the rear wheel motor 10r. In the second control mode, the front wheel motor 10f is powered and the friction braking force (rear wheel braking force B_r) is applied to the rear wheel 11r.

[0067] Accordingly, when the vehicle 100 travels forward, a more specific control mode for lifting up or lifting down the vehicle body is achieved in the cooperative process.

[0068] The driving force control method according to the present embodiment further executes the non-cooperative process of lifting up or lifting down the vehicle body only by adjusting the front wheel driving force F_f and the rear wheel driving force F_r (step S160). Further, the non-cooperative process includes the third control mode in which the front wheel motor 10f is regenerated and the rear wheel motor 10r is powered, and the fourth control mode in which the front wheel motor 10f is powered and the rear wheel 11r is regenerated.

[0069] Accordingly, in accordance with the traveling scene of the vehicle 100 or the like, it is possible to execute the lifting up or the lifting down of the vehicle body by the non-cooperative process having the high control responsiveness instead of the cooperative process as appropriate. In this description, the term "only by the adjustment of the front wheel driving force Ff and the rear wheel driving force F_r" means that the operation amount for the control of lifting up or lifting down the vehicle body includes the front wheel driving force Ff and the rear wheel driving force F_r, but does not include the friction braking force. Therefore, the above term is not intended to exclude from the technical scope of the present invention a form in which control logic that uses an operation amount other than the friction braking force to assist in lifting up or lifting down the vehicle body is included in the non-cooperative process.

[0070] Furthermore, in the driving force control method according to the present embodiment, when the vehicle 100 is traveling on the undulation road, the unevenness degree parameters (pitch rate ω_{pi}, vertical acceleration a_G, and suspension stroke amount S_{su}) indicating the size of the unevenness of the undulation road are obtained. Further, when the unevenness degree parameters exceed respective prescribed first threshold values (pitch rate threshold value ω_{piTH}, vertical acceleration threshold value a_{GTH}, and/or first stroke amount threshold value S_{suTH1}) during the execution of the non-cooperative process, the non-cooperative process is switched to the cooperative process (steps S110 to S130 and S140).

[0071] Accordingly, it is possible to appropriately select the cooperative process having the effect of reducing the vertical displacement and the non-cooperative process in which the control responsiveness is high according to the size of the unevenness in the undulation road traveled by the vehicle 100.

[0072] In particular, in the present embodiment, when the unevenness degree parameter (particularly, the suspension stroke amount S_{su}) falls below a prescribed second threshold value (second stroke amount threshold value S_{suTH2}) during the execution of the cooperative process, the cooperative process is switched to the non-cooperative process.

[0073] Accordingly, it is possible to more appropriately select the cooperative process having the effect of reducing the vertical displacement and the non-cooperative process in which the control responsiveness is high according to the size of the unevenness in the undulation road traveled by the vehicle 100.

[0074] Further, in the present embodiment, the controller 50 that functions as the driving force control device that executes the driving force control method is provided. The controller 50 controls the front wheel driving force Ff and the rear wheel driving force F_r by the front wheel motor 10f connected to the front wheels 11f of the vehicle 100 and the rear wheel motor 10r connected to the rear wheels 11r, respectively.

[0075] In particular, the controller 50 includes a cooperative process unit (step S140) that causes the adjustment of the at least one of the front wheel driving force Ff and the rear wheel driving force F_r to cooperate with the application of the friction braking force (front wheel braking force B_f or rear wheel braking force B_r) to the at least one of the front wheel 11f and the rear wheel 11r to lift up or lift down the vehicle body.

[0076] Accordingly, a configuration of the control device suitable for executing the driving force control method is achieved.

[0077] Although the embodiment of the present invention has been described above, the above embodiment is merely a part of application examples of the present invention, and does not intend to limit the technical scope of the present invention to the specific configurations of the above embodiment.

[0078] For example, in the above embodiment, the example has been described in which one of the non-cooperative process and the cooperative process is executed according to the size of the unevenness in the scene in which the vehicle 100 is traveling on the undulation road. However, the present invention is not limited thereto, and the same control can be executed in other traveling scenes in which the vertical displacement of the vehicle 100 is assumed to be reduced.

[0079] Furthermore, a specific aspect of the unevenness degree parameter is not limited to that described in the above embodiment. For example, information related to the unevenness of the undulation road may be acquired using a Lidar camera and/or any in-vehicle sensor such as a radar, and a value obtained by directly estimating the size of the unevenness from the information may be used as the unevenness degree parameter. Furthermore, parameters used for determining the switching from the non-cooperative process to the cooperative process are not limited to the unevenness degree parameters described above. For example, a configuration may be adopted in which a parameter indicating a length of a period of the mountain and valley of the unevenness of the undulation road is acquired based on information acquired from an in-vehicle server or an external server, and it is determined whether to switch from the non-cooperative process to the cooperative process based on the parameter.

[0080] In the above-described embodiment, the example has been described in which the adjustment (pitch adjustment) of the driving force distribution and the application of the friction braking force to the respective driving wheels cooperate with each other in both the first control mode (lift up control) and the second control mode (lift down control) of the cooperative process. However, the present invention is not limited thereto, and in the cooperative process, a control mode may be adopted in which the friction braking force is applied to only one of the first control mode and the second control mode. For example, a control mode may be adopted in which the front wheel braking force B_f is applied in the first control mode (lift up control) of the cooperative process, but the rear wheel braking force B_r is not applied in the second control mode (lift down control). As shown in FIG. 2, it is particularly preferable that the control logic is applied to a vehicle body structure in which, while the anti-squat angle θ_f on the front side is relatively small, the anti-squat angle θ_r on the rear side is relatively large, and a sufficient lift up and down amount can be ensured only by adjusting the driving force distribution on the rear side.

[0081] Further, in the above-described embodiment, the example has been described in which the control mode in which pitch displacement is adjusted by adjusting only the driving force distribution of the vehicle 100 is adopted as the non-cooperative process. However, instead of this, it is also possible to adopt a control mode in which the non-cooperative process is any driving force distribution (for example, the basic drive control that determines the driving force distribution during normal traveling) executed for purposes other than the purpose of adjusting the pitch displacement. For example, the technical scope of the present invention also includes a control mode in which the non-cooperative process is used as the basic drive control to achieve direct switching between the basic drive control and the cooperative process (switching without intervention of the pitch adjustment performed by the adjustment of the driving force distribution) as appropriate according to a situation of the traveling road surface such as the size of the unevenness of the undulation road.

Claims

1. A driving force control method for controlling front wheel driving force and rear wheel driving force by a front wheel motor connected to a front wheel of a vehicle and a rear wheel motor connected to a rear wheel, respectively, the driving force control method comprising:
   executing a cooperative process of lifting up or lifting down a vehicle body by cooperation of adjustment of at least one of the front wheel driving force and the rear wheel driving force and application of friction braking force to at least one of the front wheel and the rear wheel.

2. The driving force control method according to claim 1, wherein

   the cooperative process includes a first control mode in which the vehicle body is lifted up and a second control mode in which the vehicle body is lifted down,
   in the first control mode, the friction braking force is applied to the front wheel to power the rear wheel motor, and
   in the second control mode, the front wheel motor is powered, and the friction braking force is applied to the rear wheel or the rear wheel is regenerated.

3. The driving force control method according to claim 1 or 2, further comprising:

   executing a non-cooperative process of lifting up or lifting down the vehicle body only by adjusting the front wheel driving force and the rear wheel driving force, wherein
   the non-cooperative process includes a third control mode in which the front wheel motor is regenerated and the rear wheel motor is powered, and a fourth control mode in which the front wheel motor is powered and the rear wheel mo-

tor is regenerated.

4. The driving force control method according to claim 3, further comprising:

when the vehicle is traveling on an undulation road, acquiring an unevenness degree parameter indicating a size of an unevenness of the undulation road, wherein
during the execution of the non-cooperative process, the non-cooperative process is switched to the cooperative process when the unevenness degree parameter exceeds a prescribed first threshold value.

5. The driving force control method according to claim 4, wherein
during the execution of the cooperative process, the cooperative process is switched to the non-cooperative process when the unevenness degree parameter falls below a prescribed second threshold value.

6. A driving force control device that controls front wheel driving force and rear wheel driving force by a front wheel motor connected to a front wheel of a vehicle and a rear wheel motor connected to a rear wheel, respectively, the driving force control device comprising:
a cooperative process unit configured to lift up or lift down a vehicle body by cooperation of adjustment of at least one of the front wheel driving force and the rear wheel driving force and application of friction braking force to at least one of the front wheel and the rear wheel.

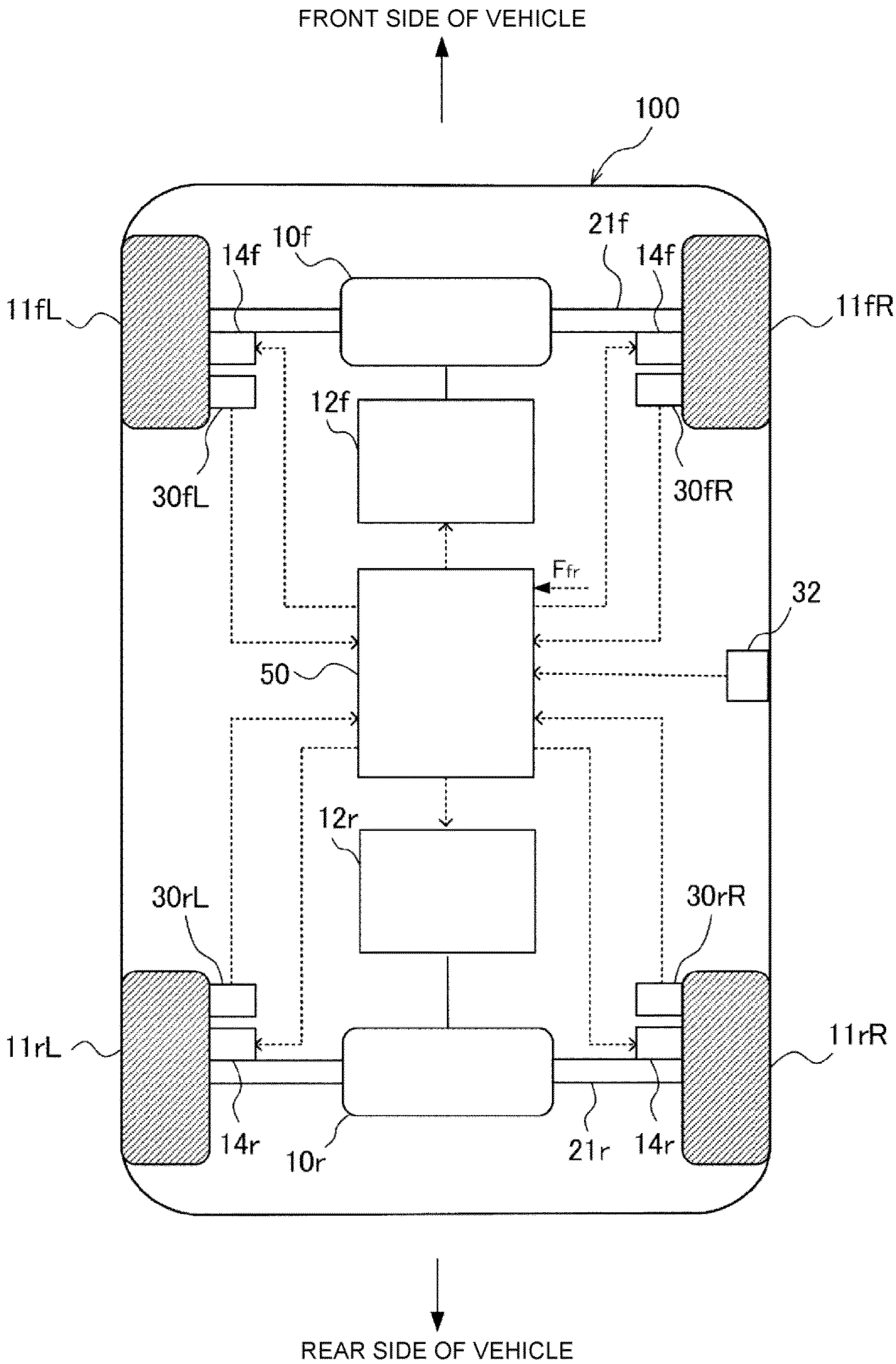

FRONT SIDE OF VEHICLE
100
10f
21f
14f
14f
11fL
11fR
12f
30fL
30fR
Ffr
32
50
12r
30rL
30rR
11rL
11rR
14r
10r
21r
14r
REAR SIDE OF VEHICLE

FIG. 1

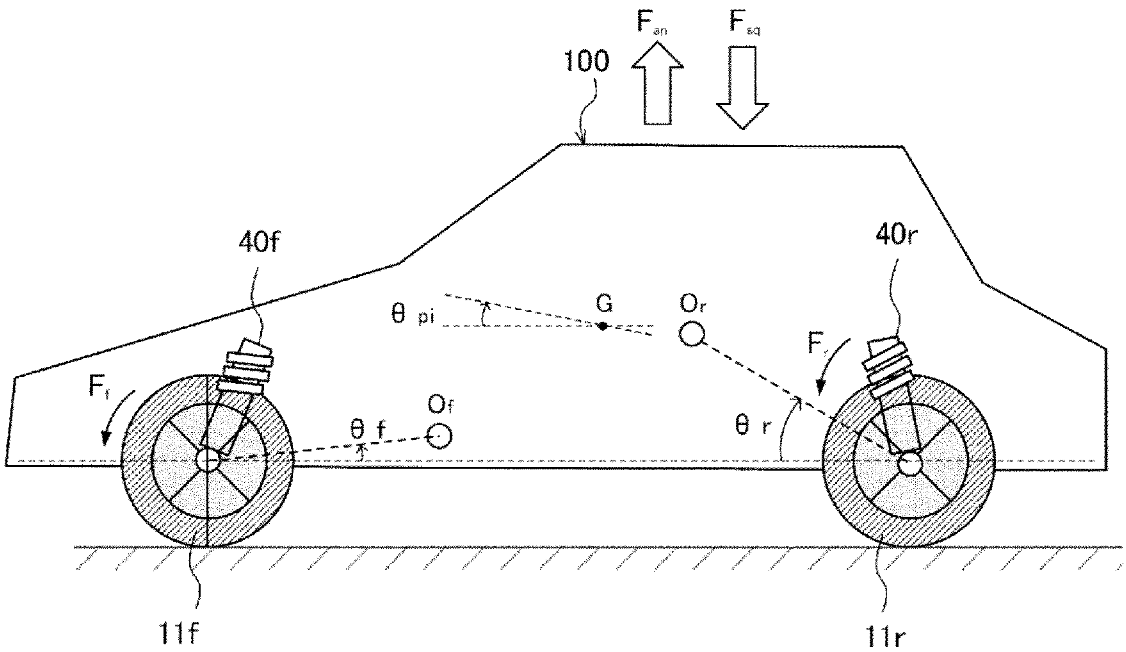


FIG. 2

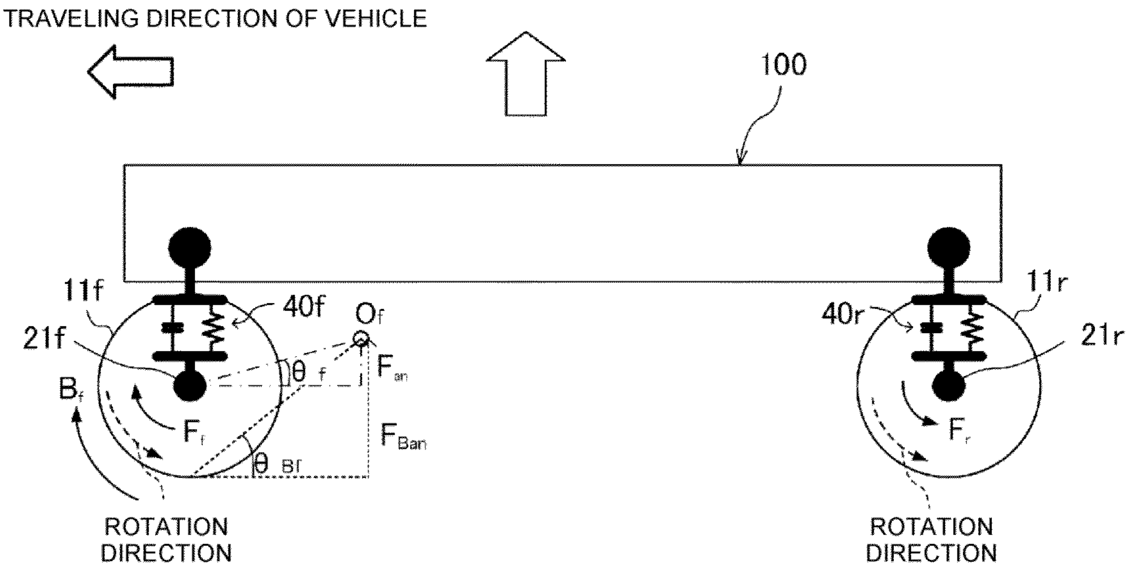

TRAVELING DIRECTION OF VEHICLE
100
11f
40f
Of
21f
θ f
Fan
Bf
Ff
FBan
θ Bf
ROTATION DIRECTION
40r
11r
21r
Fr
ROTATION DIRECTION

FIG. 3

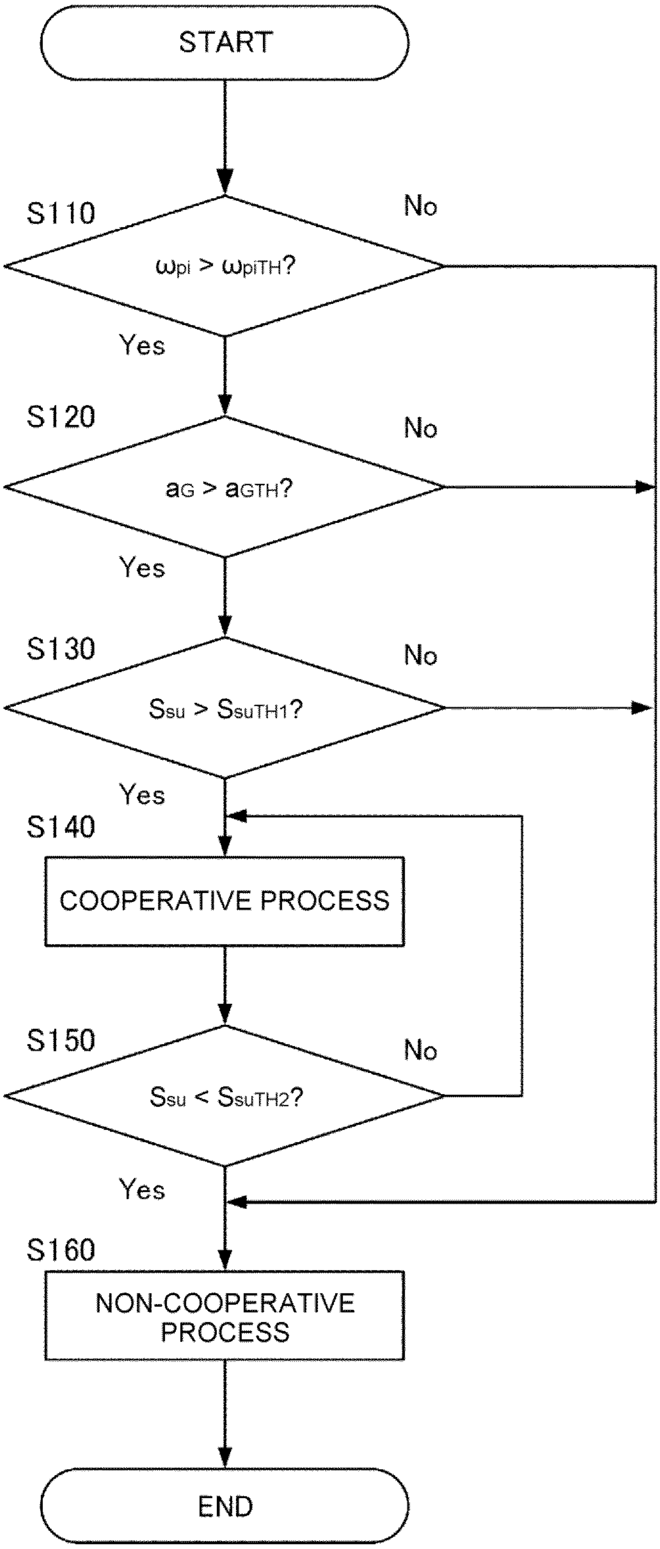
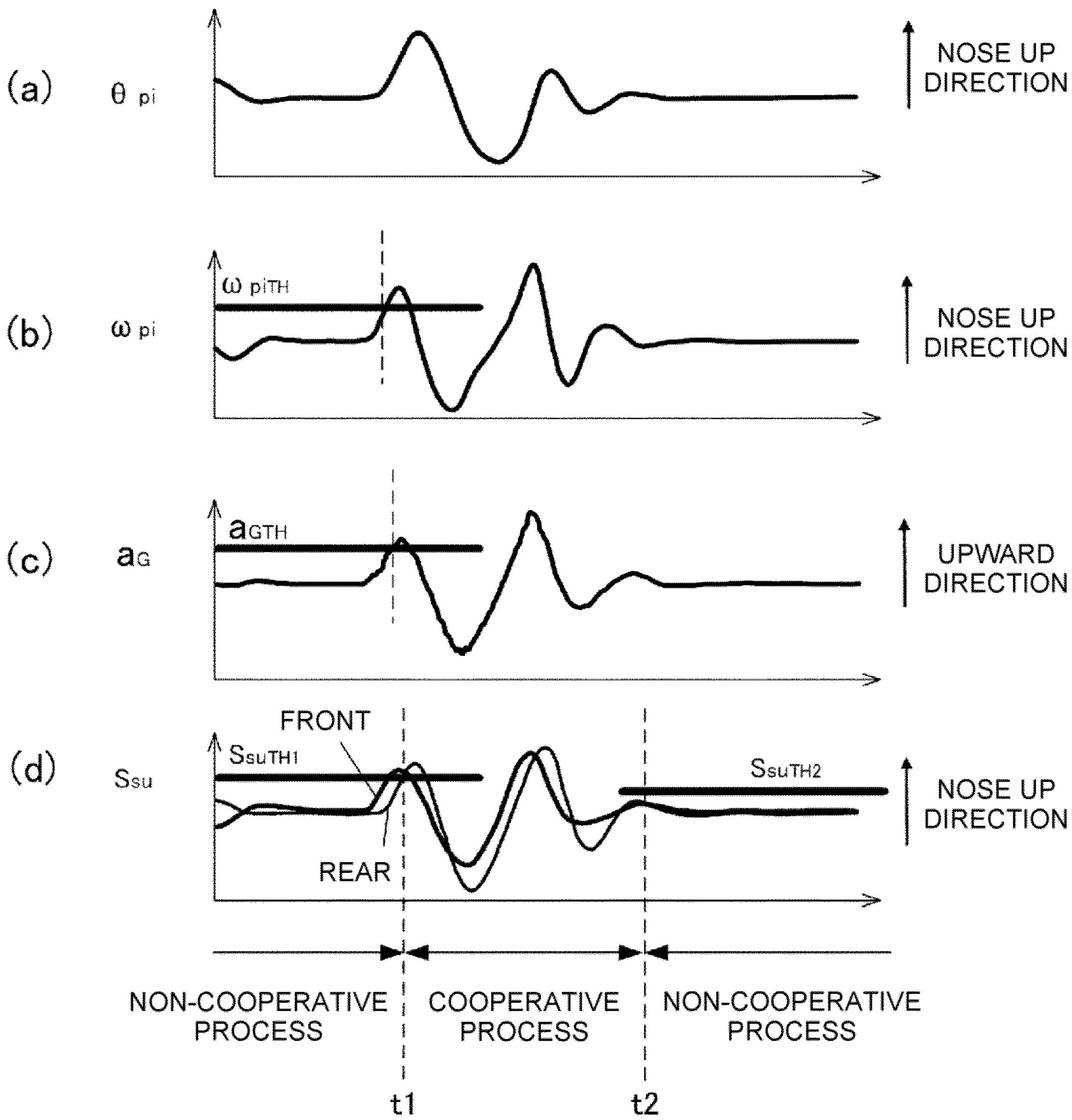

START
S110
$\omega_{pi} > \omega_{piTH}$?
No
Yes
S120
$a_G > a_{GTH}$?
No
Yes
S130
$S_{su} > S_{suTH1}$?
No
Yes
S140
COOPERATIVE PROCESS
S150
$S_{su} < S_{suTH2}$?
No
Yes
S160
NON-COOPERATIVE PROCESS
END

FIG. 4



(a)
θ pi
NOSE UP DIRECTION
(b)
ω pi
ω piTH
NOSE UP DIRECTION
(c)
aG
aGTH
UPWARD DIRECTION
(d)
Ssu
FRONT
SsuTH1
REAR
SsuTH2
NOSE UP DIRECTION
NON-COOPERATIVE PROCESS
COOPERATIVE PROCESS
NON-COOPERATIVE PROCESS
t1
t2

FIG. 5

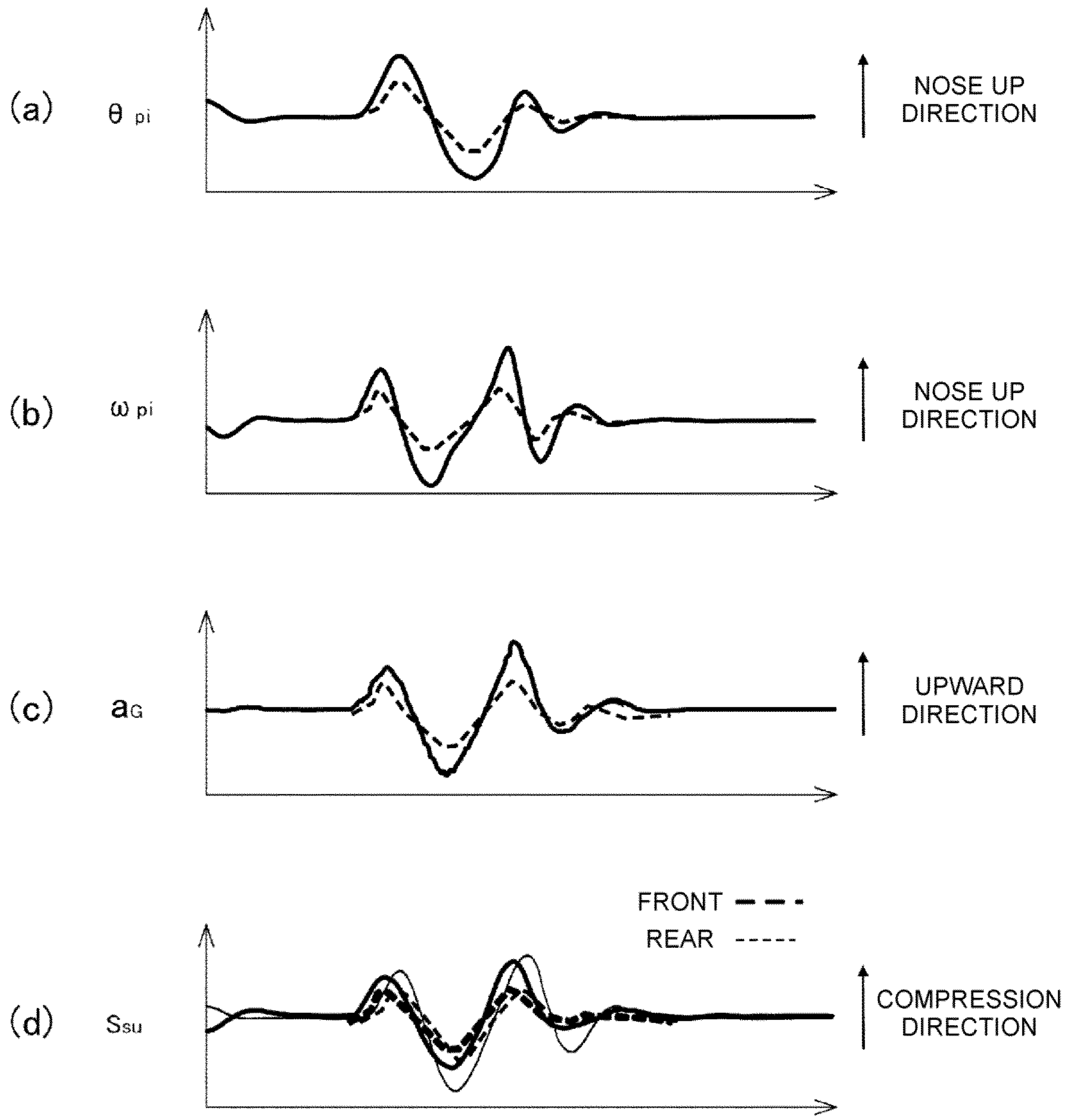

(a)
θ pi
NOSE UP DIRECTION
(b)
ω pi
NOSE UP DIRECTION
(c)
aG
UPWARD DIRECTION
FRONT
REAR
(d)
Ssu
COMPRESSION DIRECTION

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No. **PCT/JP2021/032723**

A. CLASSIFICATION OF SUBJECT MATTER

B60L 15/20(2006.01)i
FI: B60L15/20 J

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B60L15/20

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2021
Registered utility model specifications of Japan 1996-2021
Published registered utility model applications of Japan 1994-2021

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2013/069126 A1 (TOYOTA MOTOR CO LTD) 16 May 2013 (2013-05-16) paragraphs [0023]-[0089], fig. 1 ,3-4	1-3, 6
A	paragraphs [0023]-[0089], fig. 1, 3-4	4-5
A	JP 2015-71362 A (TOYOTA MOTOR CO LTD) 16 April 2015 (2015-04-16) entire text	1–6
A	JP 11-115745 A (TOYOTA MOTOR CO LTD) 27 April 1999 (1999-04-27) entire text	4-5
A	JP 2021-11133 A (NTN TOYO BEARING CO LTD) 04 February 2021 (2021-02-04) entire text	1–6
A	JP 2013-154800 A (NISSAN MOTOR CO LTD) 15 August 2013 (2013-08-15) paragraphs [0091]-[0093], fig. 26	4-5

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 October 2021	**02 November 2021**

Name and mailing address of the ISA/JP	Authorized officer
Japan Patent Office (ISA/JP) **3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915** **Japan**	Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2021/032723

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
WO 2013/069126 A1	16 May 2013	EP 2778006 A1 paragraphs [0023]-[0089], fig. 1, 3-4 US 2014/0309902 A1 CN 103917426 A	
JP 2015-71362 A	16 April 2015	US 2015/0100205 A1 entire text DE 102014219899 A1 CN 104512276 A	
JP 11-115745 A	27 April 1999	(Family: none)	
JP 2021-11133 A	04 February 2021	(Family: none)	
JP 2013-154800 A	15 August 2013	(Family: none)	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 2007118898 A **[0002]**